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RESEARCH PROGRAMS

Project Summary Report 8117-23
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Soil Air Voids Method for Compaction Control

http://www.mdt.mt.gov/research/docs/research_proj/airvoids/final_report.pdf

Introduction

The air voids approach for field compaction control represents an alternative approach to the Proctor method. The soil air voids method was initially implemented by the Montana Department of Transportation in the 1970's as an alternate approach to the traditional Proctor method of field compaction control because of its timesaving benefits and relative simplicity. The air voids approach saves time by eliminating the necessity of conducting Proctor moisture-density tests, which can delay the field compaction evaluation by one to two days. The air voids approach is simple because to evaluate the suitability of a compacted layer, the inspector only needs to plot a data point on the appropriate air voids graph.

Field compaction test results (often obtained from nuclear density gage measurements) are plotted on a graph containing an air voids line that represents the predetermined maximum acceptable value of air voids, as exemplified in Figure 1. In this example, a line representing 10% air voids is used as the limiting criteria. The field compaction test is considered passing and the lift of compacted soil is approved if the field compaction data point (dry density and water content) plots on the right side of the air voids line. A data point that falls on the left side of the air voids

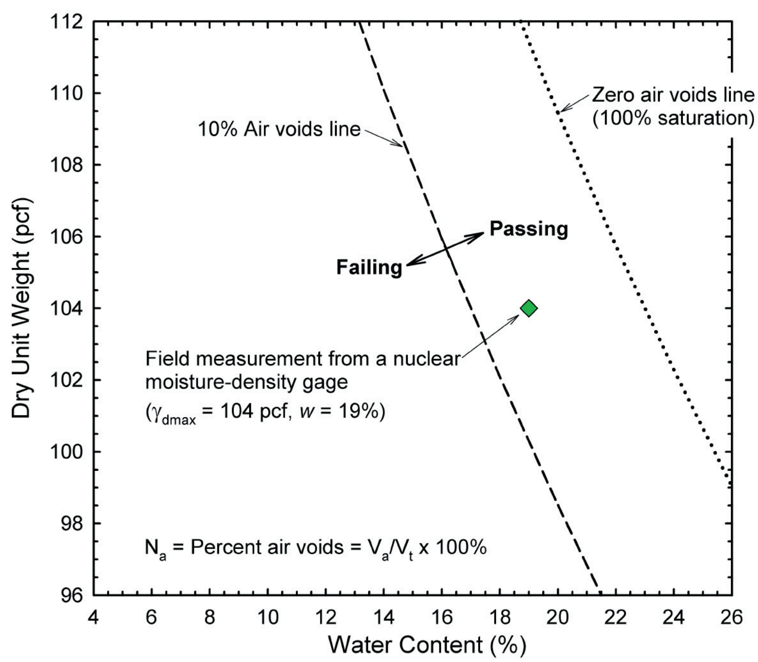

FIGURE 1. Example of the 10% air voids field evaluation method, Gs = 2.70.

line indicates the compacted soil layer does not meet the specified compaction criteria. The air voids line is a function of the soil specific gravity, G_s. As G_s increases, the air voids line will correspondingly move upwards and to the right. The zero air voids line corresponds to a condition of 100% saturation, which implies the soil voids are completely filled with water.

The air voids method has not gained widespread acceptance after being first introduced to the engineering community in the 1940's. This is likely related to potential limitations associated with lack of moisture control. The most prevalent shortcoming is that soil air voids can be reduced to relatively low values simply by increasing the soil water content.

Proponents of the air voids method point to practical (inherent) constraints of using excessive water during construction. The inherent constraint in this context presupposes that a contractor will not apply excessive water because the soil will become unworkable and will not adequately support construction equipment. In addition, water for construction can be expensive in many areas of the western U. S.; consequently, contractors are prone to use water sparingly on these projects.

Answers to the following questions were quantitatively addressed in this study. 1) Are there certain types of projects or geologic conditions in which the air voids method is suitable for evaluating soil compaction? 2) Are there specific situations in which the air voids method should not be used?

What we did

This research evaluated the suitability of the air voids method for assessing the quality of a compacted layer of soil. A literature review was conducted to examine existing published information on the air voids method and to explore previous use of the method by other agencies. In parallel with the literature review, a survey was distributed to transportation departments and other agencies throughout North America soliciting information regarding experiences that materials personnel and geotechnical engineers have had with the air voids method. Laboratory testing was conducted to gather specific information for a variety of soil types and to identify potentially suitable and potentially problematic soils. The laboratory testing program included particle size gradation, hydrometer, Atterberg limits, relative density, specific gravity, and impact compaction tests. Construction test data obtained from 20 Montana transportation projects, which included over 1,300 test results, were compiled and statistically evaluated to examine the suitability of the air voids method in regards to quantifiable trends in compaction parameters.

What we found

The air voids method does not explicitly provide the designer or field inspector a means of controlling or bounding the field compaction water content. Potential problems may occur with certain soils if inherent water content limits are relied upon during compaction. Most of the problems are associated with plastic clayey soils, and include: excessive shrink or swell, excessive settlement, reduced bearing capacity, and stability problems due to high excess pore water pressures. For these types of soils, reliance upon inherent controls of moisture during construction is too subjective of an approach on highway

projects, particularly if the inspector is not highly trained and experienced.

Based on the large amount of data reviewed in this study, it was determined that the line connecting optimum compaction values falls approximately midway between the zero air voids line and the 10% air voids line, for most materials. However, there are exceptions. For example, the line of optimums for some materials (A-7 soils in particular) may fall to the left of the 10% air voids line. This indicates that some A-7 materials may not be compatible with the air voids method because of the weak correlation between densities achieved using the Proctor impact compaction test and the corresponding air voids content. In addition, some materials may pass the air voids test but fail the conventional Proctor criteria. The area identified as the problematic region in Figure 2 is an example of this condition.

Using test results from 20 highway construction projects, it was determined that over 50% of the soils tested in these projects would have a density less than 95% of the standard Proctor maximum dry density if they had been compacted to an air voids content of 10%. Silty soil and soil with high contents of fine sand are frost susceptible. The potential for frost heave and thaw weakening problems is greatly increased if these soils are not adequately compacted. High compaction water contents and low densities (as could theoretically be achieved with improper use of the air voids method) should be avoided, particularly when frost susceptible soils are encountered.

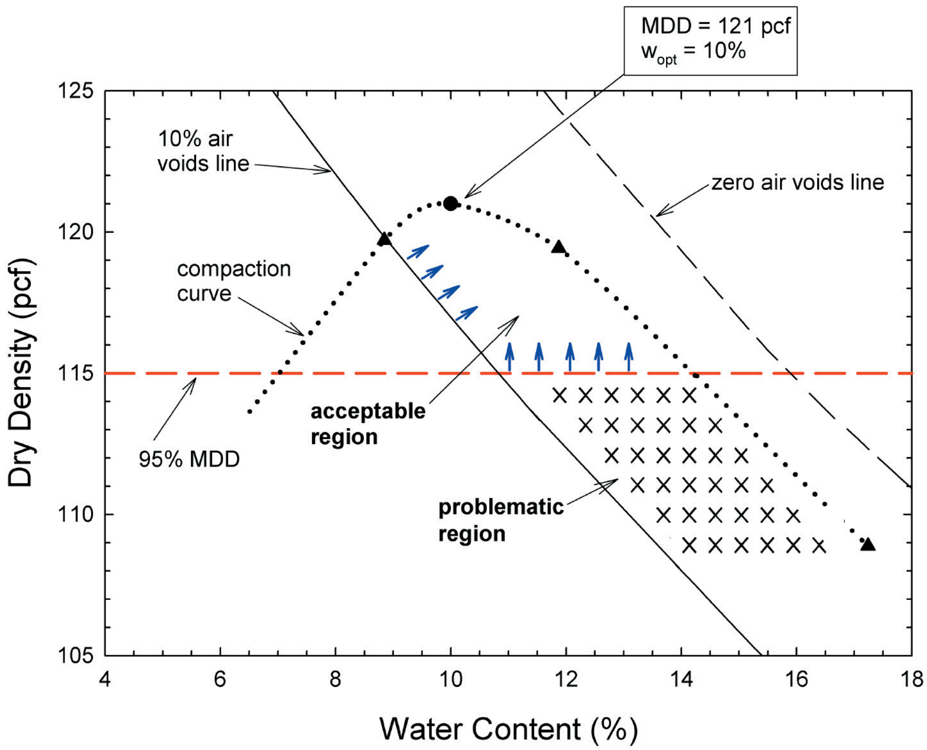

FIGURE 2. Standard Proctor compaction curve for A-2-7(1) soil.

What the researchers recommend

The researchers involved with this study recognize the advantages and practicality of the air voids method. The method is advantageous because a field inspector can rapidly determine if a compacted soil layer meets the specified compaction criteria without obtaining a soil sample for laboratory Proctor compaction testing. However, based on laboratory tests and analyses of data from highway construction projects, it appears this method should be considered applicable on a limited basis, only. The use of the air voids method should be restricted to smaller projects in which the relationship between air voids content and percent relative compaction is carefully established during design, and the contract earthwork specifications provide a means of controlling and monitoring the compaction water content. In addition, the air voids method may not be suitable if tests indicate the specific gravity of materials varies significantly along the project alignment. Statistical analyses and cooperative laboratory tests conducted during this study indicate a typical standard deviation of specific gravity is about ± 0.065.

For More Details . . .

The research is documented in Report FHWA/MT-05-010/8117-23, *Soil Air Voids Method for Compaction Control.*

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MDT Implementation Status
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It was determined that the Zero Air Voids method is a proven tool for controlling compaction in instances when a proctor is not available or multiple materials are being mixed. The Materials Bureau will use this report in conjunction with the results of an ongoing study looking at the Department's Quality Assurance (QA)/ Quality Control (QC) program. The current compaction control specifications will be rewritten to reflect the findings of the two studies. It is anticipated this rewrite will reduce the use of the Zero Air Voids method of compaction control to instances when a proctor is not available or when an accurate proctor cannot be selected because of the mixing of materials.

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